RESEARCH DEPARTMENT

LINE-STORE STANDARDS CONVERSION: SUBJECTIVE EFFECT OF UNCONVERTED COMPONENTS

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SUMMARY

This report describes experiments that were carried out in order to investigate the subjective effects of interference caused by 'break-through' of unconverted input signal to the output of a 625-line/405-line line-store standards converter. The effects of two different forms of 'break-through' were investigated; the first form was that which would result from an aperiodic coupling between the input and output of the converter and the second form was that resulting from a differentiating coupling. Experiments were carried out using pictures derived from slides, and curves have been plotted showing how the subjective effect of the two forms of interference varied with the amplitude of the interfering signal for three different types of subject matter.

1. INTRODUCTION

In a line-store standards converter[1] the redistribution of the video information on a new time scale is carried out by means of some form of 'redistributing' store. One form of such a store contains a pair of electronic switches and a storage device for each picture element in one line of the display. One of the problems of this method of conversion is that it is instrumentally difficult to avoid a certain amount of 'break-through' of the input signal to the output, resulting in an interference pattern on a display of the output signal. The experiments described in this report were carried out in order to investigate the subjective effect of various levels of this interference and the results of these experiments help in specifying an acceptable limit to the spurious coupling which could be tolerated across the switches and storage devices in a converter.

2. DETAILS OF EXPERIMENT

2.1. Description of Apparatus

A block diagram of the equipment used to simulate the effect of 'break-through' in a line-store standards converter is shown in Fig. 1. The two flying-spot scanners shown in this figure used identical slides; one scanner operated at the in-

put standard of the simulated conversion while the other operated at the output standard. In the tests, one scanner provided a 625-line video signal of 5 Mc/s bandwidth and the other scanner provided a 405-line video signal of 3 Mc/s bandwidth.

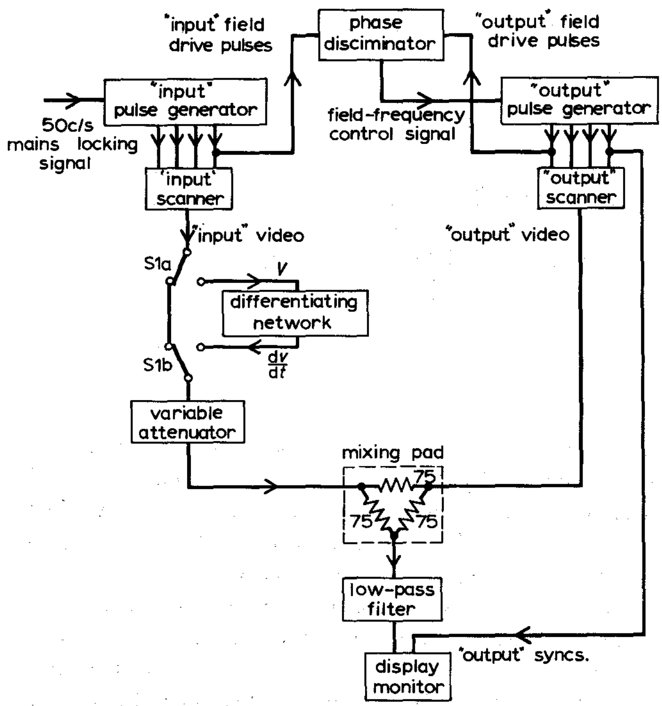


Fig. 1 - Block diagram of apparatus

In line-store standards conversion, the field pulses of the input and output standards must be maintained precisely in phase with one another. In order to maintain this condition as rigidly as possible, the synchronizing-pulse generator of one scanner was controlled by a signal obtained from a phase-discriminator that compared the phases of the two trains of field-drive pulses. The residual jitter in the relative timing of these pulses had a magnitude of about 2 μs peak-to-peak, and a mean frequency of less than 1 c/s, this jitter being superimposed on a long term drift that was sufficiently slow to avoid increasing the visibility of the interfering signal. Tests showed that at levels near the threshold of visibility, the more rapid jitter had little effect on the results.

The switch S1 selected the type of 'break-through' to be simulated; the two types investigated were 'break-through' via (a) an aperiodic network and (b) a differentiating network, the latter network being the 'first derivative' path of an equalizer type TV/EQ/12. The amplitude of the interfering signal was controlled by a calibrated variable attenuator. The wanted signal plus interference was limited in bandwidth by a low-pass filter appropriate to the output line-standard, (3 Mc/s for 405 lines, 5 Mc/s for 625 lines).

After passing through the filter, the signal was finally displayed on a 21-inch (53 cm) monitor synchronized by pulses from the output-standard pulse generator. Neither the wanted nor the unwanted video signals were accompanied by synchronizing pulses, since these would almost certainly be absent in the switch and store sections of a converter.

2.2. Conditions of Tests

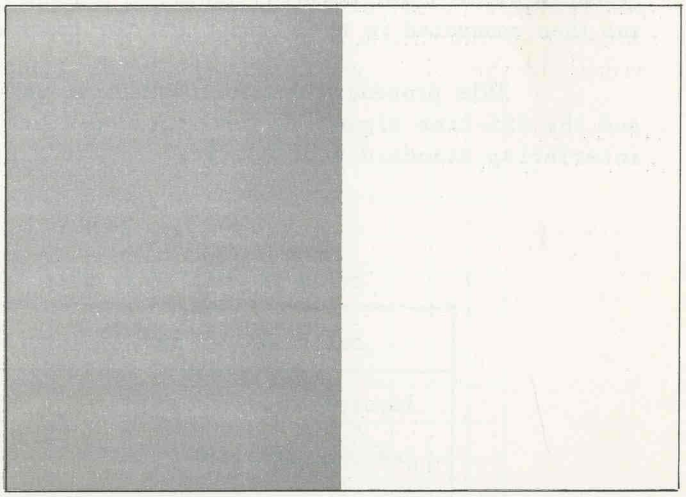
The monitor was adjusted to give a brightness of 20 ft-L (215 asb) for a signal input corresponding to white and the ambient lighting was such that the monitor screen reflected about 0·25 ft-L (2·7 asb) when the cathode-ray tube beam current was cut off.

Tests were carried out using three different slides; these are shown in Fig. 2. The slide of the grey-white step was constructed in order to give the greatest possible visibility of interference at a given amplitude of interfering signal. The grey left-hand half of the wanted signal display obtained from this slide was adjusted to a brightness of 1 ft-L, (10·7 asb) so as to be close to that brightness at which an added interfering signal giving a stationary pattern would be most visible under the given viewing conditions (see Appendix). A signal corresponding to white was used for the right-hand half of this display in order to provide the maximum amplitude of interfering signal.

Slides 2 and 3 were chosen to show the difference in the subjective effect of the interference in two types of scene; slide 2 contained a large proportion of plain area, while slide 3 contained much detailed information.

2.3. Experimental Procedure

With the switch S1 in the position that by-passed the differentiating network, various levels of the input signal were added to the output signal. The subjective effect of the resulting interference on the display was assessed by six observers who were seated at between five and seven times the picture height from the monitor. These observers were asked to express their results according to the scale



Slide 1 - Grey-white step

Slide 2 - Girl with fan

Slide 3 - V.I.P. studio

Fig. 2 - Slides used in tests

given in Table 1 for each of the three slides in turn. The differentiating network was then connected in the circuit and the tests were repeated.

This procedure was followed first using the 405-line signal as interference and the 625-line signal as the wanted picture, and secondly with 625 lines as the interfering standard and 405 lines as the wanted standard.

TABLE 1

Scale of Subjective Effect of Interference

Subjective Effect of Interference	Score
Imperceptible	1
Just perceptible	2
Definitely perceptible but not disturbing	3
Somewhat objectionable	4
Definitely objectionable	5
Unusable	6

3. EXPERIMENTAL RESULTS

The results of the tests are shown in Figs. 3 and 4 in which the average marking of the six observers has been plotted against the attenuation, in decibels, of the interfering signal relative to the wanted output signal.

Since the attenuation of a differentiating network is dependent on frequency, being given by:

$$\text{Attenuation (dB)} = c - 20 \log_{10} f$$

where f = frequency

and c = constant,

the horizontal axis in Fig. 4 has been calibrated in terms of the network attenuation at a particular frequency, i.e. 3 Mc/s. The horizontal axes of both Figs. 3 and 4 are calibrated in terms of the attenuation provided by unwanted coupling between the input and output of a converter, relative to the attenuation provided by the wanted coupling. In Fig. 3, a value of 0 dB corresponds to wanted and unwanted couplings having equal attenuations; in Fig. 4, a value of 0 dB corresponds to an unwanted coupling that provides an attenuation at 3 Mc/s which is equal to the attenuation provided by the wanted (aperiodic) coupling.

Considering Fig. 3, the results show that, when the interfering signal was coupled to the wanted signal via an aperiodic network, it was necessary to attenuate the interfering signal by at least 47 dB relative to the wanted signal in order that

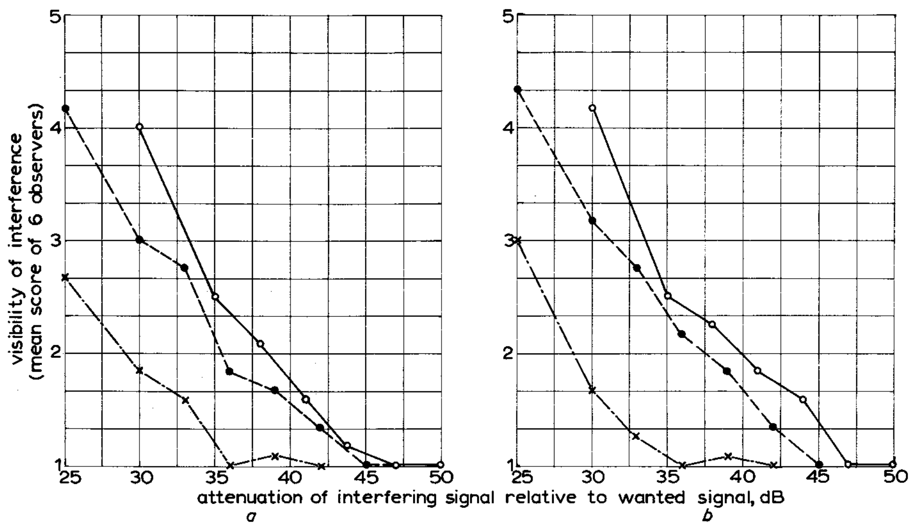


Fig. 3 - Visibility of interference when interfering signal added via an aperiodic network

a 405-line interfering signal added to 625-line wanted signal
b 625-line interfering signal added to 405-line wanted signal

Slide 1 - Grey-white step
Slide 2 - Girl with fan
Slide 3 - V.I.P. studio

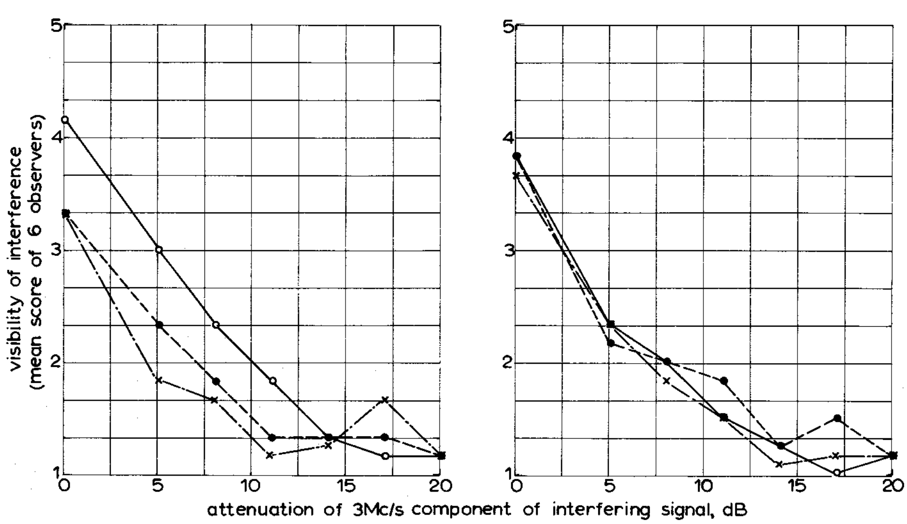


Fig. 4 - Visibility of interference when interfering signal added via a differentiating network

a 405-line interfering signal added to 625-line wanted signal
b 625-line interfering signal added to 405-line wanted signal

Slide 1 - Grey-white step
Slide 2 - Girl with fan
Slide 3 - V.I.P. studio

it be imperceptible on the most critical scene used in the tests; further, the attenuation required to produce a given visibility of interference, using the most critical slide, was about 10 dB greater than that required with the least critical slide. The reason for a given amount of interference being least visible on slide (3) was probably due to the fact that this slide contained much detailed information and few large plain areas, with the result that the interference tended to be masked by the wanted information.

The results plotted in Fig. 4 show that, when the interfering signal was coupled to the wanted signal through a differentiating network, it was necessary to attenuate the 3 Mc/s component of the interfering signal by at least 16 dB in order to render the interference imperceptible when using the most critical slide. The fact that several of the curves in Fig. 4 show a minor peak between 14 dB and 20 dB is considered to be of no significance and was probably caused by observers confusing fine detail in the wanted picture with the interference when the latter had a very low level. It can also be seen that, with a differentiating coupling, the attenuation required in order to produce a given visibility of interference was less dependent on the type of slide display than when the coupling was aperiodic, especially when using a 405-line display. This effect was probably due to the fact that the masking effect of detailed information in the wanted picture was counteracted by an increase in the level of interference caused by high-frequency video signals arising from detailed information.

Finally, both Figs. 3 and 4 show that interchanging the line standards of the wanted and interfering signals made little difference to the visibility of the interference for a given attenuation in the coupling network.

4. CONCLUSIONS

In a 625/405 line-store standards converter, any spurious coupling of an aperiodic nature between the input and output should have an attenuation of at least 47 dB, relative to the wanted coupling, if the resulting interference is to be imperceptible. With an attenuation of 40 dB, the interference will be just perceptible on the most critical scenes.

If the input is spuriously coupled to the output through a differentiating network then, taking the amplitude of the 3 Mc/s component of the input signal as a reference level, the attenuation provided by the spurious coupling at 3 Mc/s relative to that provided by the wanted (aperiodic) coupling must be at least 16 dB in order that the interference on the display of the output signal should be imperceptible. This figure of 16 dB at 3 Mc/s corresponds to an attenuation at a frequency f Mc/s given by:

$$\text{Attenuation (dB)} = 16 + 20 \log_{10} (3/f) \text{ dB.}$$

where the video frequency f is expressed in Mc/s.

An attenuation of 10 dB allows the interference to be just perceptible on the most critical scenes. Interchanging the standards of the input and output signals makes, in general, less than 1 dB difference to the attenuation required for a given visibility of interference.

The above results were obtained using still pictures only; with moving pictures the attenuation of the unwanted signal required for a given visibility of interference can be somewhat higher[2] since there would be relative movement between the interference and the wanted picture detail. The attenuation increase required by moving scenes would probably be about 6 dB when the interference is definitely visible, but the attenuation required for interference at the threshold of perception would probably be about the same for moving pictures as still pictures.[3]

5. REFERENCES

1. 'An Outline of Synchronous Standards Conversion Using a Delay-Line Interpolator', Research Department Report No. T-096, Serial No. 1962/31.

2. Schade, Otto H., 'Optical and Photoelectric Analog of the Eye', J. Opt. Soc. Am., September 1956, Vol. 46, No. 9.

3. 'Line-Store Standards Conversion: Subjective Effect of Switch and Store Tolerance', Research Department report in preparation.

4. Moon, P., and Spencer, D.E., 'The Visual Effect of Non-Uniform Surrounds', J. Opt. Soc. Am., March 1945, Vol. 35, No. 3.

5. 'The Variation in the Visibility of Interference Over the Grey Scale of a Television Picture', Research Department Report No. T-092, Serial No. 1962/27.

APPENDIX

Relative Visibility over the Grey Scale on a Television Display of an Interfering Signal added to the Displayed Signal

This Appendix describes a method of calculating the variation in the visibility of an interfering signal over the grey scale of a television display. The results obtained show how the visibility of interference is affected by the following factors:

(a) The gamma of the display tube transfer characteristic.

(b) The luminance of an unexcited area of the display caused by ambient illumination and flare in the tube.

(c) The adaptation condition of the eye viewing the display.

The calculations are based on two assumptions, these being as follows:

(i) It is assumed that the luminance B of a display tube is related to the applied signal voltage E by the equation:

$$B - B_0 = AE^{\gamma} \qquad (1)$$

where B_0 = luminance of an unexcited area of the display caused by ambient illumination and flare in the tube.

and A and γ are constants.

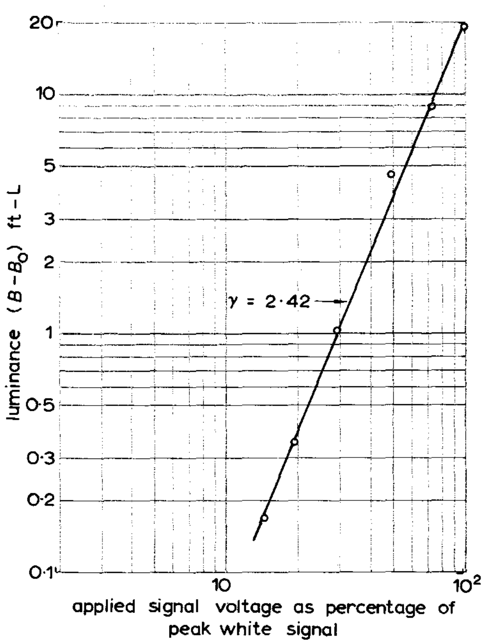


Fig. 5 - Luminance $(B - B_0)$ plottea against applied signal voltage

The errors involved in this assumption are quite small for the display tube used in the experiments described in this report; Fig. 5 shows a curve of luminance plotted against applied signal voltage which was obtained from a similar type of display tube.

If the maximum luminance B_M results from an applied signal of amplitude E_M, then:

$$A = (B_M - B_0)/E_M^{\gamma} \qquad (2)$$

Therefore, from equations (1) and (2):

$$(B - B_0/B_M - B_0) = (E/E_M)^{\gamma} \qquad (3)$$

By differentiating equation (3), it can be seen that the difference ΔB in the luminances of two areas on the display, caused by a small difference ΔE in the applied signal voltages, may be conveniently expressed as:

$$\Delta B \simeq \gamma(B_M - B_0/B - B_0)^{1/\gamma}. \ (B - B_0) \ . \Delta E/E_M \qquad (4)$$

(ii) It is assumed that, under the adaptation conditions of the eye existing when an average television display is being viewed, the difference ΔS in the sensations caused by light from two adjacent areas differing in luminance by a small amount ΔB is given by:

$$\Delta S = k\,\Delta B/(B + B_1) \tag{5}$$

where B = luminance of the brighter of the two areas

B_1 = constant for a given adaptation condition of the eye

k = constant for two areas of a given shape subtending a given angle at the fovea of the eye.

Equation (5) is an approximation to a formula given by Moon and Spencer;[4] their data were obtained from experiments carried out in order to determine the threshold of perception of the difference in luminance between a circular object field and a surrounding annular test field, these fields subtending angles of 1° and 1½° at the fovea of the eye respectively. (See Fig. 6.)

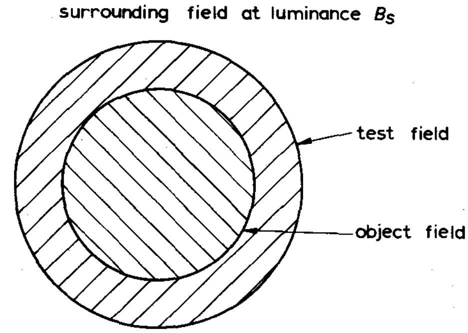


Fig. 6 - Fields used in Moon and Spencer experiments

In Fig. 7, a comparison has been made between curves obtained from the Moon and Spencer formula and from equation (5). These curves show the variation in the Fechner fraction with luminance for three different adaptation conditions of the eye.

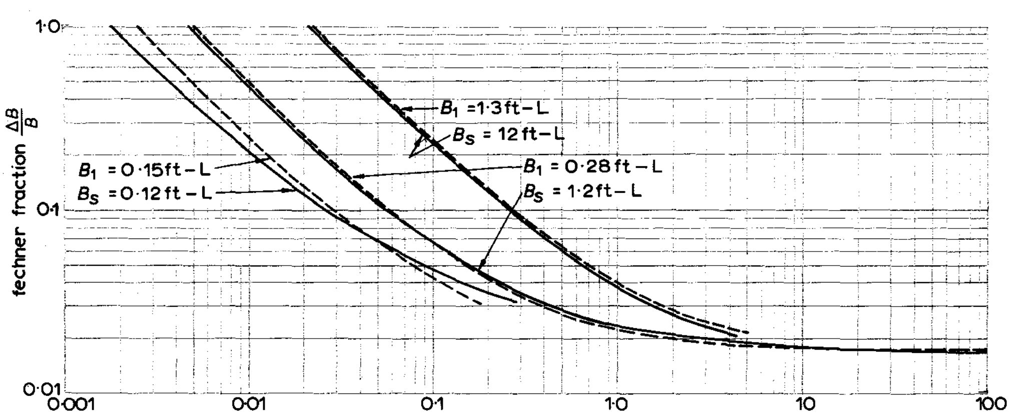


Fig. 7 - Variation of Fechner fraction with luminance of test field

——— Curves given by Moon and Spencer formula for threshold of perception

– – – – Curves given by $\Delta S = k\,\Delta B/(B+B_1)$ plotted for $\Delta S/k = 0{\cdot}017$

The Moon and Spencer curves have been plotted for the adaptation conditions existing when the whole of the field surrounding the test field is at a constant luminance, denoted by B_s in Fig. 7. The values of $\Delta S/k$ and B_1 in equation (5) were chosen so that the curves obtained fitted the Moon and Spencer curves as closely as possible. It can be seen that there is close agreement between the two sets of curves except when the surrounding luminance is very low.

It is of interest to note that if equation (5) were a true representation of the relation between luminance and sensation, then departures of the Fechner fraction $\Delta B/B$ from a constant value could be explained by assuming that a veiling glare of luminance B_1 exists in the eye. This assumption would mean that the luminance perceived by the eye would be $B + B_1$ and hence for a given difference in sensations ΔS,:

$$\Delta Be/Be = C$$

where Be (the luminance perceived by the eye) $= B + B_1$

and C is a constant.

From equations (4) and (5), the difference in the sensations caused by the light from two adjacent areas on a television display which differ in brightness as the result of an interfering signal of amplitude ΔE, is given by:

$$\Delta S = k\gamma\ (B_M - B_0/B - B_0)^{1/\gamma}\ .\ (B - B_0/B + B_1)\ .\ \Delta E/E_M \tag{6}$$

For a given value of ΔE, ΔS reaches a maximum value at a brightness given by:

$$B = \gamma B_0 + (\gamma - 1)\ B_1 \tag{7}$$

Suitable values for B_0, B_1 and γ applicable to the tests described in the report are:

$$B_0 = 0{\cdot}25 \text{ ft-L } (2{\cdot}7 \text{ asb})$$

$$B_1 = 0{\cdot}3 \text{ ft-L } (3{\cdot}2 \text{ asb})$$

$$\gamma = 2{\cdot}4$$

Inserting these values in equation (7) gives 1·02 ft-L (10·9 asb) as the brightness at which ΔS reaches a maximum.

A curve obtained from equation (6) is shown in Fig. 8. This figure shows the attenuation (dB) of an added interfering signal which is required to maintain the visibility of the interference (i.e., ΔS) constant plotted against the luminance of the area of the display on which the interference is superimposed.

Also given on this figure is an experimental curve obtained by Geddes.[5] This curve was obtained from subjective tests on the visibility of stationary interfering patterns on a television display; the maximum luminance of the display was 20 ft-L (215 asb) while the luminance of unexcited areas was 0·25 ft-L (2·7 asb).

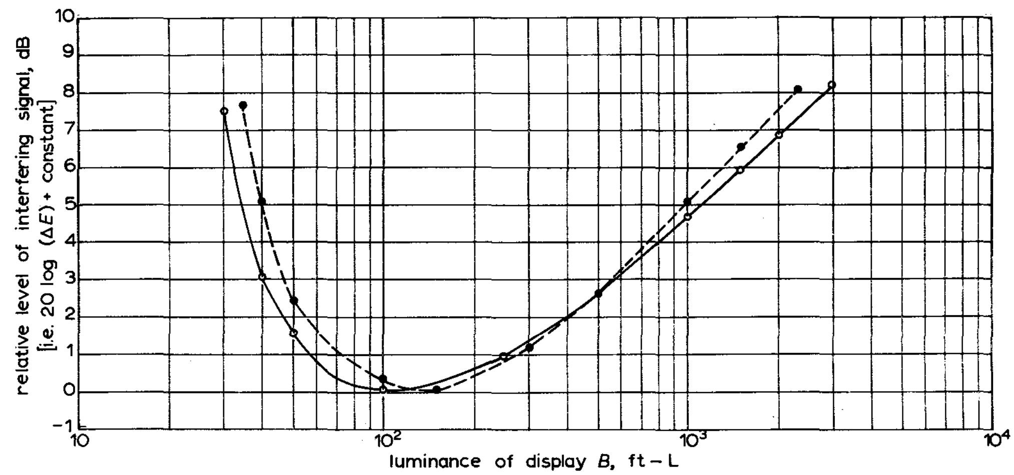


Fig. 8 - Relative amplitude of interfering signal to produce constant visibility of interference plotted against luminance of display

——— Curve obtained from equation $\Delta E/E_M = \Delta S/k\gamma.(B + B_1/B - B_0)\cdot(B - B_0/B_M - B_0)^{1/\gamma}$ plotted for B_0 = 0·25 ft-L (2·7 asb), B_1 = 0·3 ft-L (3·2 asb), γ = 2·4

------ Experimental curve obtained by Geddes.[5] B_0 = 0·25 ft-L (2·7 asb)

Differences between the theoretical and experimental curves are to be expected since certain approximations have been made in the theoretical analysis, the most important of which are:

(a) It has been assumed that the transfer characteristic of a display tube can be expressed in terms of a constant value of γ equal to 2·4, whereas the experimental results are related to the transfer characteristic of an actual display tube.

(b) As mentioned above, equation (5) relating sensation and brightness is not entirely correct. In addition, the value of B_1 used in this equation is somewhat arbitrary and varies according to the experimental conditions.

Equation (6) can also be used to predict, quantitatively, the ratio $\Delta E/E_M$ of interfering to wanted signal at which the interference appearing on a display corresponds to the threshold of perception. For a value of $\Delta S/k$ = 0·017, equation (5) was found to agree substantially with the curve representing the Moon and Spencer data corresponding to the threshold of perception (see Fig. 7). (It should be noted that this value of $\Delta S/k$ only applies to experimental conditions similar to those used by Moon and Spencer; with test fields subtending smaller angles at the fovea of the eye $\Delta S/k$ would be greater.) In the tests described in this report, the peak value E_M of the wanted signal corresponded to a luminance B_M of 20 ft-L (215 asb). Substituting the aforementioned values of B_0, B_1, B_M, $\Delta S/k$ and γ in equation (6) gives:

$$20 \log \Delta E/E_M = -50 \text{ dB}$$

when B = 1·02 ft-L (10·9 asb)

This figure compares quite well with the experimental figure of -47 dB which was obtained for the 'Grey-White Step' display (see Fig. 3).

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